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Seasonal and Population Growth Parameters of Southern Lake Winnipeg Saugers.

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Seasonal and population growth parameters of southern Lake Winnipeg saugers.

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ABSTRACT

A comparative growth study of saugers, *Stizostedion canadense*, from southern Lake Winnipeg was undertaken in 1979 and 1980. Female saugers attain a larger asymptotic size at a faster rate than do male saugers. Saugers are recruited into the southern Lake Winnipeg fishery at a mean age of 3+ years.

Seasonal growth rates of young-of-the-year and yearling saugers were not significantly different between 1979 and 1980 but the 1980 growth curves were significantly higher than their 1979 counterparts. This difference in elevation is related to the elevation differences between 1979 and 1980 water temperature curves. Yearling saugers began growing in June and ceased growth in mid-September. Young-of-the-year sauger growth also ceased in mid-September.

Both young-of-the-year and yearling saugers consumed Chironomidae larvae exclusively during spring but changed their diet during the summer months and fed almost exclusively on emerald shiners.

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INTRODUCTION

The sauger, *Stizostedion canadense*, is restricted to the freshwaters of North America. It occurs from the St. Lawrence - Champlain system south, west of the Appalachian Mountains to the Tennessee River in Alabama, southwest to northern Louisiana, northwest through eastern Oklahoma to central Montana and central Alberta, and east below James Bay to Quebec (Scott and Crossman 1973). Saugers prefer to inhabit large shallow lakes which are turbid with colloidal clay suspension, or large, turbid, slow flowing rivers (Scott and Crossman 1973, Priegel 1969, Doan 1949).

Saugers are exploited heavily by the commercial fisheries on the south basin of Lake Winnipeg. Saugers and walleyes have been commercially fished since the 1880's in this area (Skaptason 1929). Sauger production has been steadily declining in the south basin due to overexploitation.

Information on age and growth of saugers in Canada is scarce. Various aspects of its life history in Canada were described by Doan (1941), Hart (1928), Bajkov (1930), Kennedy (1949), and Deason (1933). Southern sauger populations in the United States were described by Carlander (1949), Carufel (1963), Priegel (1969), Koenst and Smith (1975), Walburg (1972), Hassler (1955, 1957, 1958), Vanicek (1964), and Nelson (1968, 1972). Exploitation and environmental factors affecting sauger growth rates were discussed in the above studies.

The objectives of this study were:

1) To describe seasonal growth of young-of-the-year and yearling saugers from the south basin.
2) To estimate length of time it takes young-of-the-year saugers to be recruited into the commercial fisheries on the south basin.
3) To describe the entire growth regime of saugers in the south basin.
4) To compare growth of south basin saugers to growth in other lakes.

Description of Study Area

In this study, the south basin is defined as that portion of Lake Winnipeg south of Grindstone Point (Fig. 1). The south basin has a area of 2,780 km^2 and an average depth of 9.7 meters (Brunskill *et al.* 1979).

The Winnipeg River and the Red River are the two major river systems that enter the south basin. The Winnipeg River flows from the east through Precambrian Shield. The Red River flows from the south through a sedimentary agricultural area. The south basin of the lake supports an active walleye and sauger commercial fishery. 538,768 kilograms of sauger were harvested in 1979 summer and fall season and 1980 winter season combined.

The south basin has turbid water with Secchi disc visibility from 0.1 to 1.0 m (Brunskill *et al.* 1979). These turbid conditions are due mostly to two factors; the heavy sediment load carried by the Red River which is dumped into the basin and the shallow depth of the basin which can cause considerable resuspension of sediments due to strong wind and wave action (Brunskill *et al.* 1979). Water temperature in the south basin reaches a maximum of 21 - 23^{o}C in the summer and cools rapidly in the fall.

The majority of the young-of-the-year and yearling saugers were collected at Patricia Beach (Fig. 1). This site was choosen because of its accessibility, successful catch records of previous years, and hard sand bottom idealy suited for fyke netting and seining.

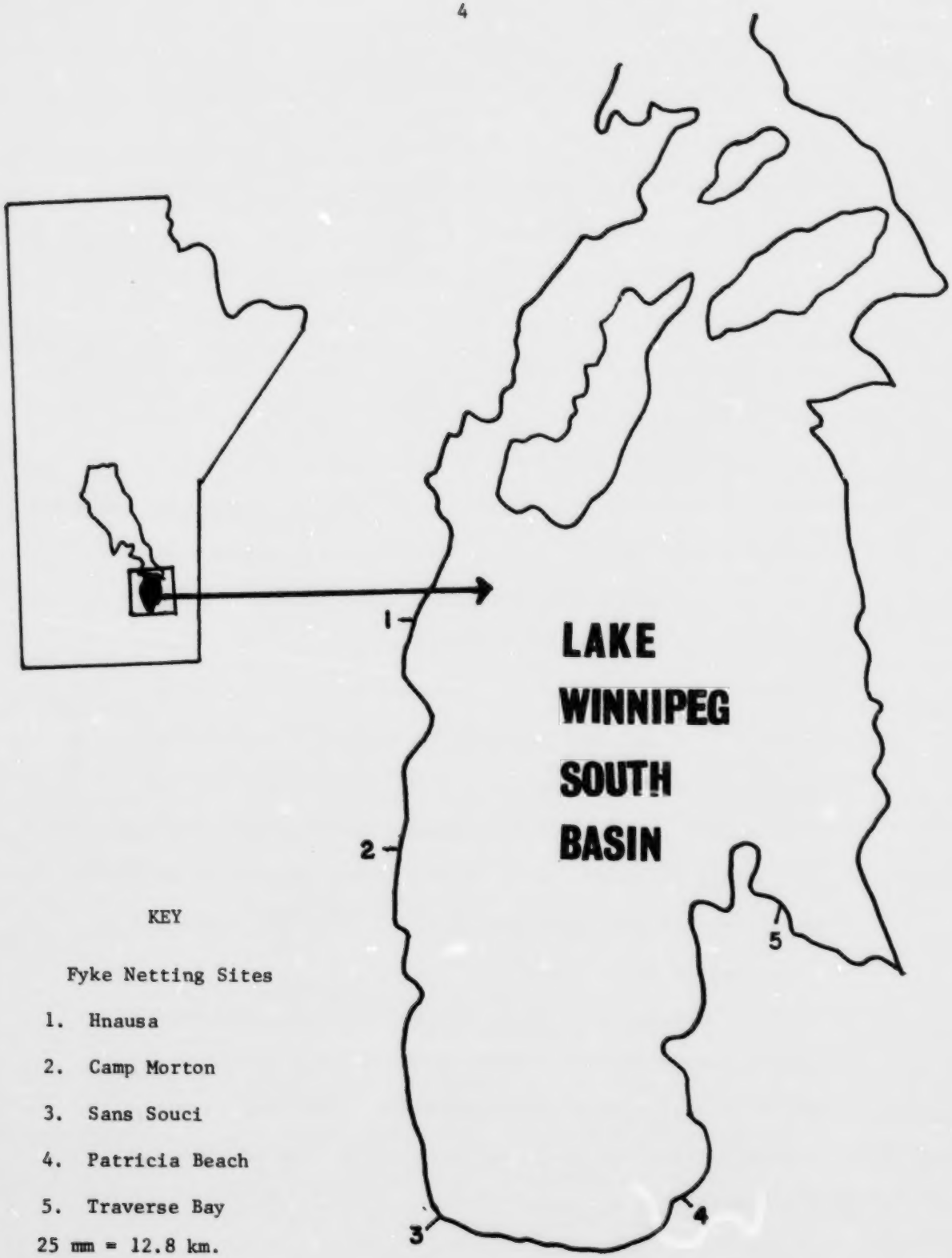
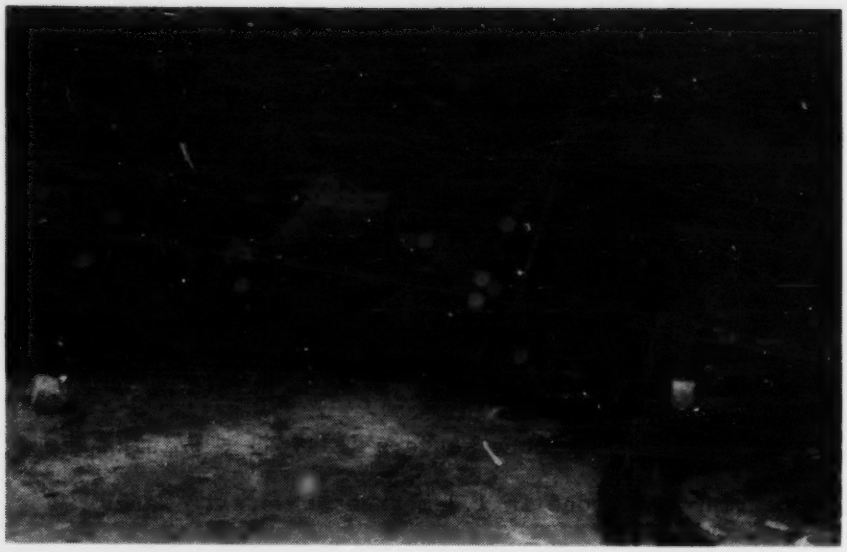


Fig. 1. Location of fyke netting and seining sites on the south basin of Lake Winnipeg.

METHODS AND MATERIALS

Age and growth information is based on data from 1,610 saugers collected from the south basin of Lake Winnipeg. Young-of-the-year (y-o-y) and yearling sauger were collected at two week intervals during the 1979 and 1980 open water seasons. Two fyke nets (1.2 m front frame, 3 mm oval mesh, 7.6 m wings, 30.5 m lead) and a 30.5 m seine net (3 mm oval mesh) were used to catch young saugers (Fig. 2) . Seining and fyke netting were done in 1.2 metres of water. Water temperatures were recorded for each set. Young saugers (44 mm - 120 mm) were identified by the "color spot" technique as described by Priegel (1969). Larger saugers were collected in the fall with gangs of experimental gill nets composed of the following meshes: 7.62 cm, 8.26 cm, 9.53 cm, 10.80 cm, 12.70 cm cm and 13.34 cm. Commercial sauger catches from 7.62 cm mesh nets were also sampled in the fall.

The fork length (mm) of each sauger was recorded. The sex of each sauger with the exception of y-o-y and yearlings were determined according to Olynyk (1980). Otoliths were taken from each fish and aged according to Erickson (1979). Stomach contents of 120 y-o-y and 140 yearlings were examined and recorded. Routine statistical analysis were performed according to Snedecor and Cochran (1967) and according to Ricker (1975). All growth parameters were derived from analysis of age-specific mean lengths. Total lengths of saugers from other lakes were converted to fork length according to Carlander (1950).



A

B

Fig. 2. Example of fyke net (A) and seine (B) used to catch young saugers.

RESULTS

Young-of-the-year

Seasonal growth

The y-o-y attained a mean fork length of 86.81 mm in 1979 and 123.5 mm in 1980 (Fig. 3). Fig. 4 shows four y-o-y each collected in successive four week intervals. There was no evidence of winter growth as mean fork lengths were similar in the late fall as they were the following spring when the young-of-the-year were classified as yearlings. The majority of growth took place in water temperatures ranging from 16°C to 22°C (Fig. 3). Growth ceased in mid-September when water temperatures reached 6°C.

Stomach Contents

Until the y-o-y attain a fork length of 50 mm (mid-July), they feed exclusively on Chironomidae larvae. After attaining a mean fork length of 50 mm, y-o-y diversify their diet and ingest mostly fish flesh. Emerald shiners *(Notropis athernoides)*, were the main diet of the young-of-the-year saugers (Table 1).

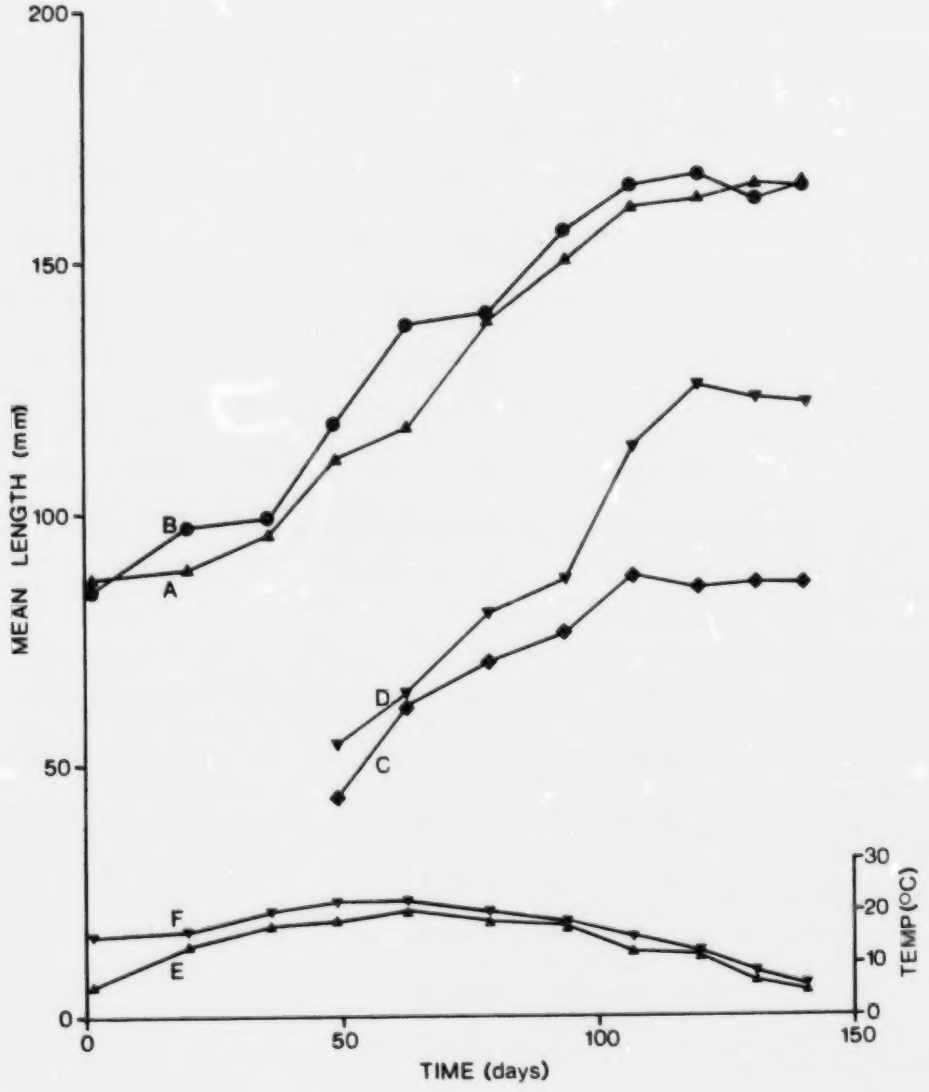


Fig. 3. Seasonal growth of saugers and temperature changes in southern Lake Winnipeg. A - 1979 yearlings. B - 1980 yearlings. C - 1979 young-of-the-year. D - 1980 young-of-the-year. E - 1979 surface water temperatures. F - 1980 surface water temperatures.

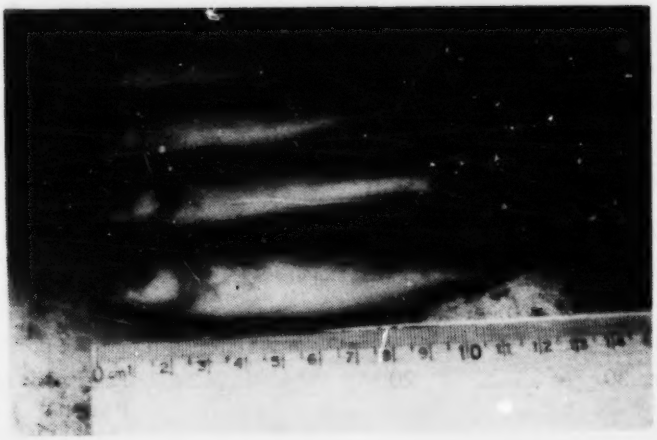


Fig. 4. A sample of 4 young-of-the-year saugers collected at 4 week intervals from mid-July to mid-October showing growth differences for each month.

Table 1. Seasonal changes in stomach contents of young-of-the-year saugers over the 1979 and 1980 study period. Percentage of stomachs containing food items are listed for 1979 and 1980 combined.

Date	No. Fish	Stomach contents	
July 16	20	Chironomidae	70%
		Empty	30%
July 30	20	Emerald shiners	50%
		Perch	20%
		Chironomidae	10%
		Unidentified	10%
		Empty	10%
August 15	20	Emerald shiners	55%
		Perch	30%
		White bass	10%
		Empty	5%
August 30	20	Emerald shiners	45%
		Perch	25%
		White bass	10%
		Unidentified	10%
		Empty	10%
September 12	20	Emerald shiners	35%
		Perch	15%
		White bass	10%
		Sauger	5%
		Empty	35%
September 25	20	Emerald shiners	40%
		Perch	20%
		Unidentified	15%
		White bass	5%
		Empty	20%

Yearlings

Seasonal growth

The yearlings attained a mean fork length of 163.74 in 1979 and 165.53 mm in 1980 (Fig. 3). Growth commenced in June and ceased in mid-September during both years. Fig. 5 shows a collection of six yearling saugers each collected in successive monts began with May ending at October. There was no evidence of winter growth. Greatest size increments occurred in water temperatures of 17°C to 22°C (Fig. 3).

Stomach Contents

During the early spring, the yearling's diet consisted mainly of Chironomidae larvae and fish. By mid-June the diet consisted exclusively of fish dominated by emerald shiners. Perch yearlings were the second most important species in the yearling saugers' diet (Table 2).

Time of annulus formation

Otoliths were sampled from the yearling sauger through out the spring and early summer to determine when the first annulus appeared. In 1979 the first annulus could not be detected until the first week in July. In 1980, the first annulus was not detected until mid-June. Figure 6 shows the position of the first annulus when it first appears in early summer and at the end of the growing season in mid-September.

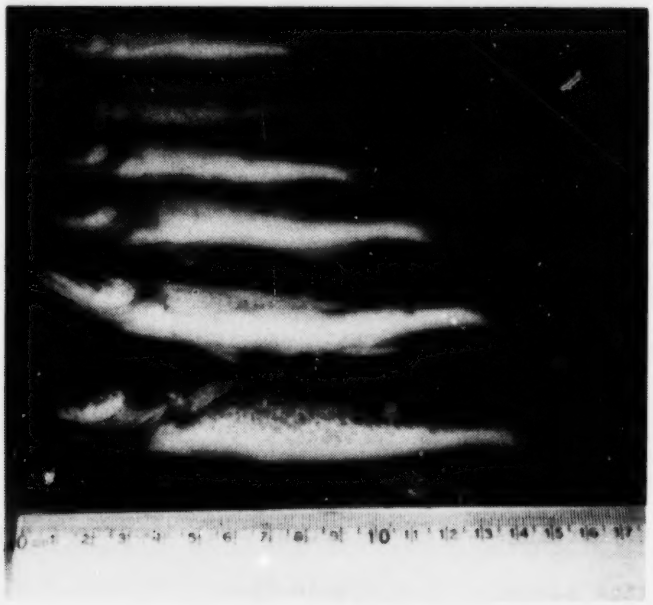
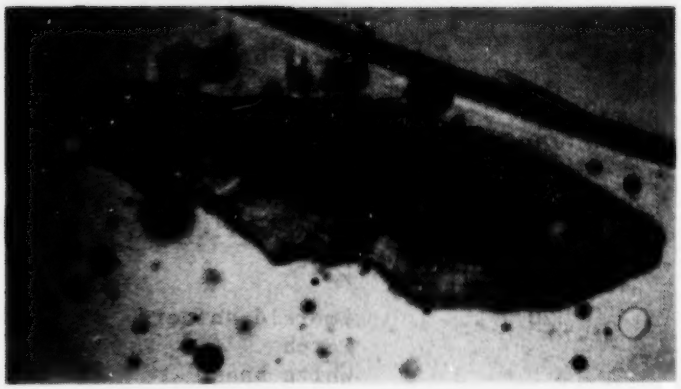


Fig. 5. A sample of 6 yearling saugers collected at 4 week intervals from mid-May to mid-October showing growth differences for each month.

Table 2. Seasonal changes in stomach contents of yearling saugers. Percentage of stomachs containing food items are listed.

Date	No. of Fish	Stomach Contents	
May 28	20	Chironomidae	45%
		Emerald shiners	20%
		Unidentified	20%
		Empty	5%
June 17	20	Emerald shiners	65%
		Perch	20%
		Unidentified	10%
		Empty	5%
July 16	20	Emerald shiners	45%
		Perch	20%
		Sauger	5%
		Carp	5%
		White bass	5%
		Unidentified	5%
		Empty	15%
July 30	20	Emerald shiners	50%
		Perch	30%
		White bass	10%
		Empty	10%
August 30	20	Emerald shiners	65%
		Perch	20%
		Sauger	5%
		Unidentified	5%
		Empty	5%
September 25	20	Emerald shiners	45%
		Perch	25%
		White bass	5%
		Sauger	5%
		Unidentified	10%
		Empty	10%

A



B

Fig. 6. Position of the first annulus on a sauger yearling otolith collected in late June (A) and in yearling sauger otolith collected in mid-September (B). The dot indicates the annulus. Both saugers were collected in the 1980 study period.

Growth regimes of the southern Lake Winnipeg stock

Age-specific mean length (irrespective of sex) of southern saugers (Table 3, Figs. 7 and 8) and sex-specific, age-specific mean lengths of southern saugers (Table 4, Figs. 7 and 8) were fitted to exponential and von Bertalanffy growth models.

The 1980 asymptotic length was 18 mm longer than the 1979 asymptotic length (Table 5, Figs. 9 and 10). The first point on the 1980 Walford plot (Fig. 10) was deleted because the resulting L_∞ was very close to the maximum observed length in the 1980 sample. Inclusion of the mean length of 2 year old males in the 1979 Walford plot resulted in a higher correlation coefficient, R, and a higher estimate of L_∞ (Table 5, Fig. 11) which was very close to the maximum observed length in the 1979 male sample. Exclusion of the mean length of 8 year old females from the 1979 Walford plot resulted in a higher R and lower L_∞ which again more closely estimated the maximum observed length in the 1979 female sample (Table 5, Fig. 12).

The maximum observed mean length in the 1980 male sample, 315.56, was closely approximated by the Walford plot when the first point was deleted (Table 5, Fig. 13). This deletion also resulted in a higher R.

A reliable (more than 5 fish age class^{-1}) maximum observed length of 1980 females, 353.82 mm, was also closely approximated by the Walford plot when the first point was deleted (Table 5, Fig. 14). This deletion also resulted in a higher R.

Table 3. Age-specific mean lengths of southern basin saugers, 1979 and 1980.

Age (years)	Year					
	1979			1980		
	Mean length (mm)	1 S.E.	Sample size	Mean length (mm)	1 S.E.	Sample size
0	86.8	0.80	115	123.5	0.65	61
1	163.7	1.21	149	165.5	0.98	238
2	232.7	3.22	18	214.2	2.24	46
3	259.0	2.29	48	284.9	2.95	27
4	282.4	1.97	95	316.6	1.25	139
5	299.5	3.27	108	323.4	1.20	177
6	301.4	3.16	57	319.4	1.79	120
7	298.6	6.31	25	331.2	6.37	27
8	303.2	6.52	15	321.5	5.92	19
9	297.8	7.64	4	316.3	7.70	7
10	-	-	-	300.0	-	1
11	-	-	-			
12	-	-	-			
13	-	-	-			
14	356.0	-	1			

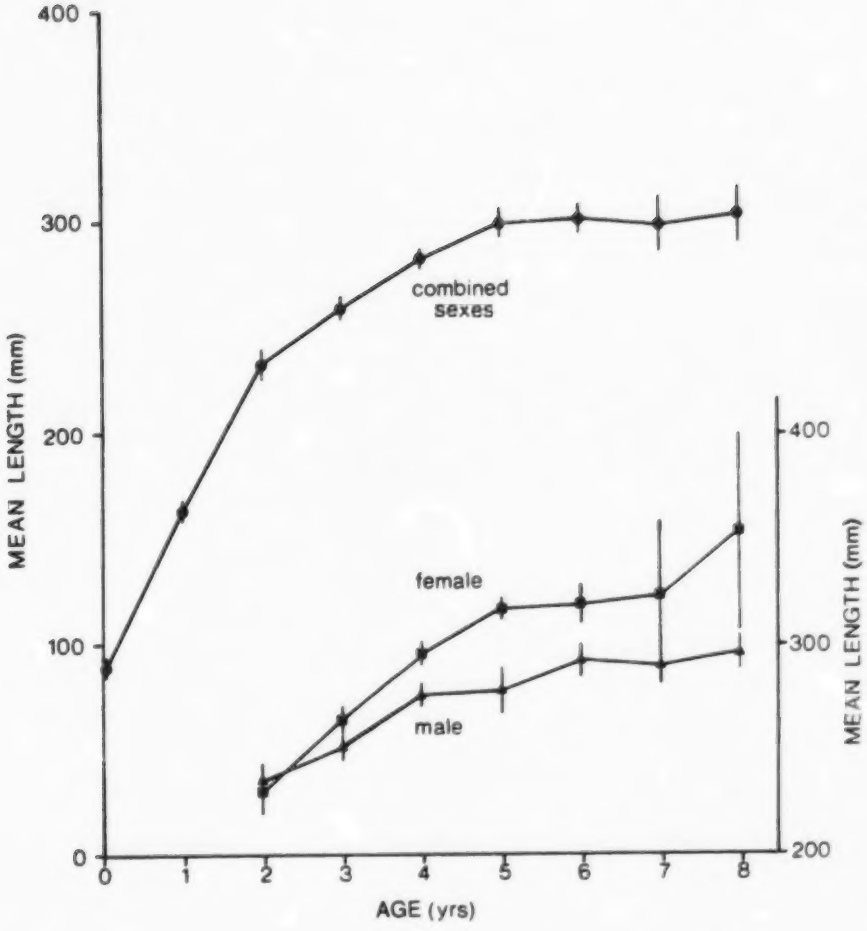


Fig. 7. Age-specific mean lengths of southern saugers during 1979. Vertical bars indicate $\pm$ 2 S.E.

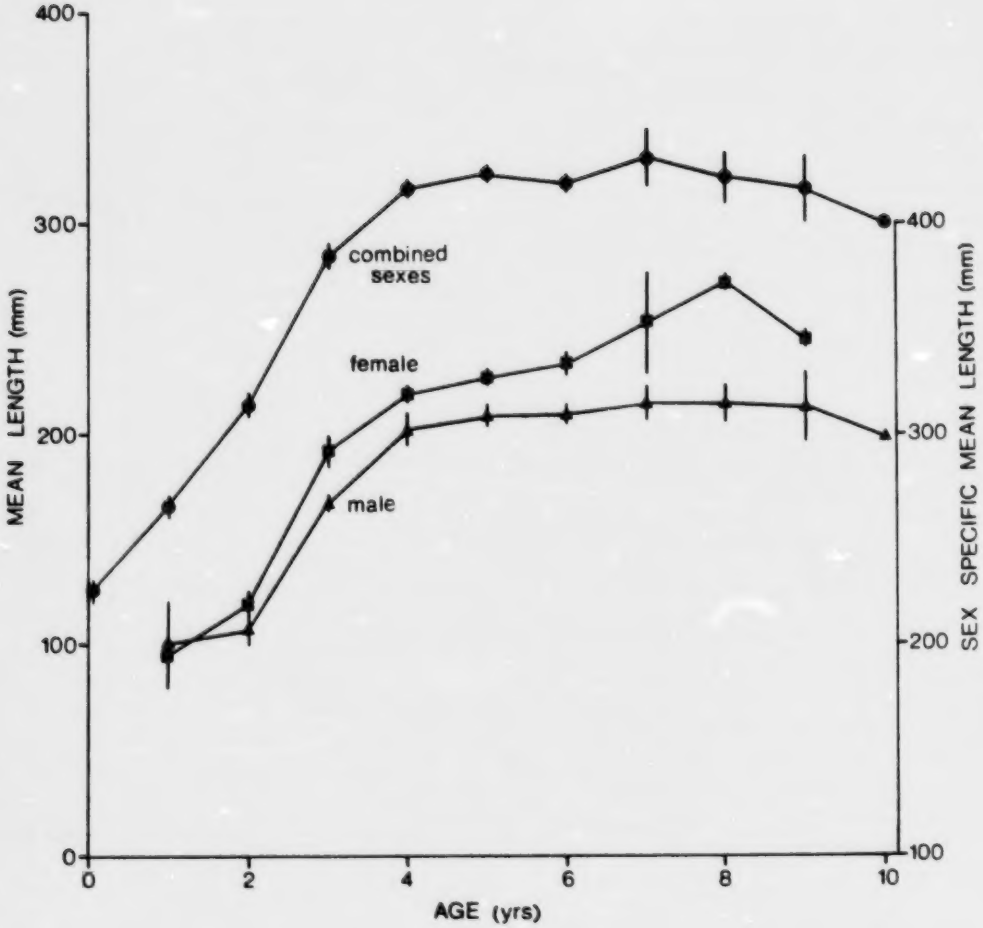


Fig. 8. Age-specific mean lengths of southern saugers during 1980. Vertical bars are $\pm$ 2 S.E.

Table 4. Sex specific, age specific mean lengths of southern basin saugers, 1979 and 1980.

Age (years)	Year											
	1979						1980					
	Males			Females			Males			Females		
	Mean length (mm)	1 S.E.	Sample size	Mean length (mm)	1 S.E.	Sample size	Mean length (mm)	1 S.E.	Sample size	Mean length (mm)	1 S.E.	Sample size
1							201.2	10.08	4	196.1	6.13	6
2	235.0	4.06	9	230.3	5.12	9	208.0	3.10	23	220.1	2.86	21
3	250.9	2.92	19	264.2	2.91	29	268.4	0.97	9	293.2	3.15	16
4	275.5	2.24	62	295.3	2.61	33	303.2	3.80	18	320.0	1.42	85
5	277.3	5.32	47	316.6	2.42	61	309.7	2.22	39	327.8	1.52	92
6	292.0	3.37	37	318.5	4.50	20	310.4	1.84	72	334.1	2.53	43
7	289.2	4.27	18	322.5	17.37	7	315.5	3.77	16	353.8	11.89	11
8	295.5	3.70	13	353.0	23.00	2	315.4	4.19	17	373.0	25.00	2
9	297.7	7.64	4				314.0	7.90	5	346.0		1
10							300.0		1			
11												
12												
13												
14	356.00	-	1									

Table 5. Walford plots for various sets of sauger length data, 1979 and 1980.

Curve type	Equation	L_∞ (mm)	R	Test F value and d.f.
1979 combined sexes ages 0 - 8	$L_{t+1} = 117.996 + 0.662L_t$	312	0.990	281.98 (1,6)
1979 males, ages 2 - 8	$L_{t+1} = 100.865 + 0.664L_t$	300	0.991	19.45 (1,4)
1979 males, ages 3 - 8	$L_{t+1} = 167.103 + 0.429L_t$	292.5	0.776	4.53 (1,3)
1979 females, ages 2 - 8	$L_{t+1} = 93.404 + 0.750L_t$	372	0.932	26.50 (1,4)
1979 females, ages 2 - 7	$L_{t+1} = 123.613 + 0.631L_t$	335	0.975	57.12 (1,3)
1980 combined sexes ages 0 - 9	$L_{t+1} = 98.258 + 0.712L_t$	340.8	0.958	78.85 (1,7)
1980 combined sexes ages 1 - 9	$L_{t+1} = 136.632 + 0.586L_t$	330	0.934	40.92 (1,6)
1980 males, ages 1 - 9	$L_{t+1} = 97.562 + 0.701L_t$	326	0.898	25.10 (1,6)
1980 males, ages 2 - 9	$L_{t+1} = 185.251 + 0.414L_t$	315.8	0.979	112.64 (1,5)
1980 females, ages 1 - 7	$L_{t+1} = 100.913 + 0.735L_t$	381	0.919	21.69 (1,4)
1980 females, ages 2 - 7	$L_{t+1} = 193.833 + 0.441L_t$	346.8	0.936	21.07 (1,3)

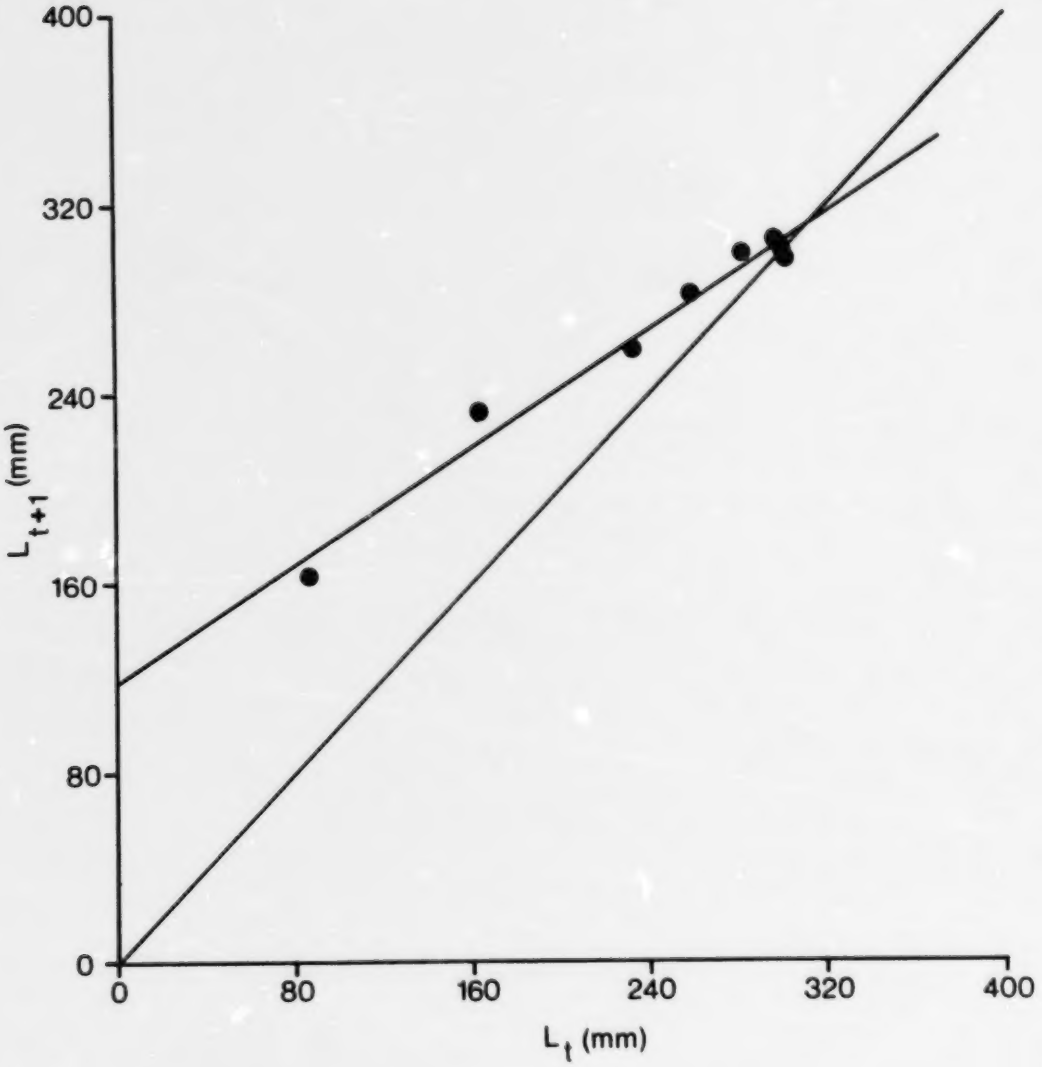


Fig. 9. Walford plot of mean lengths of all 1979 saugers.

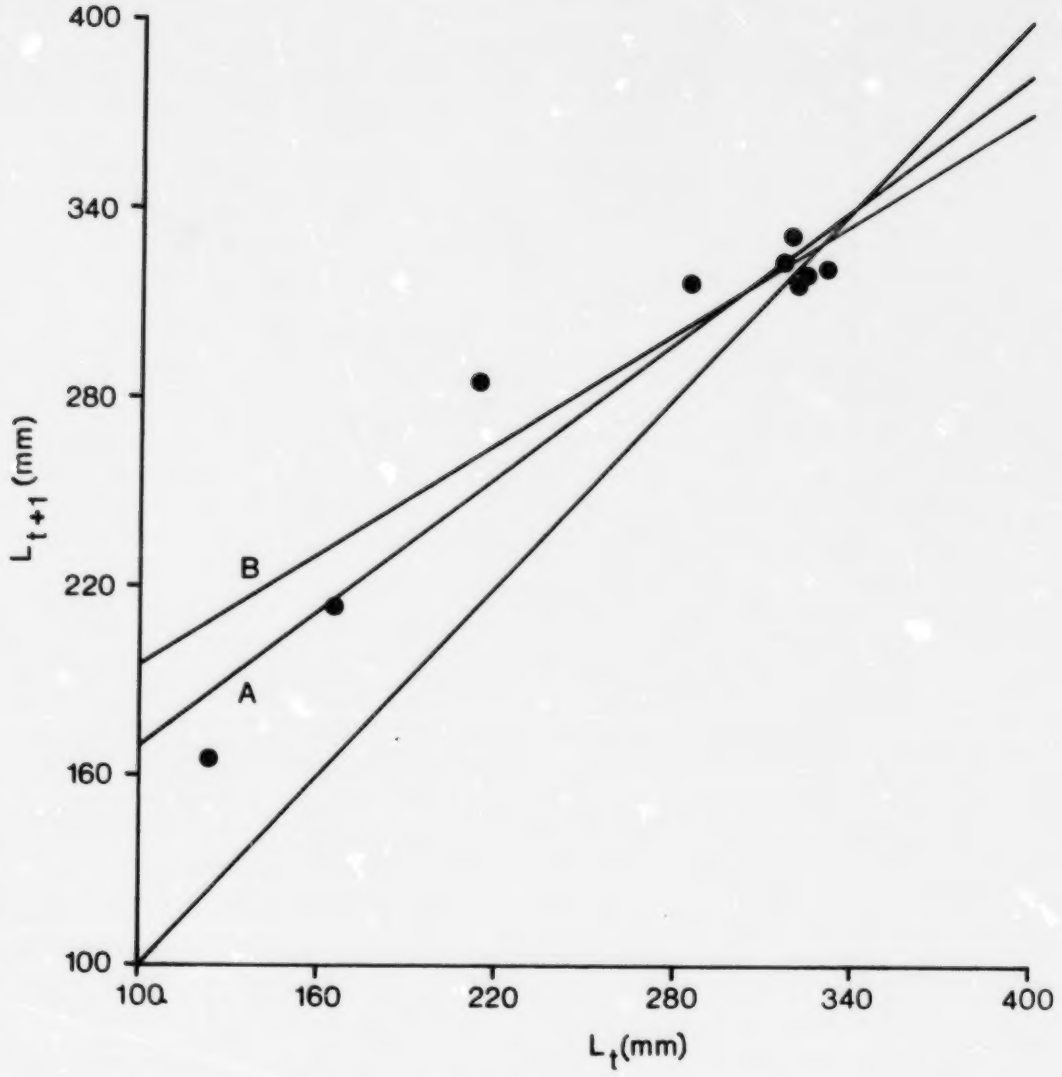


Fig. 10. Walford plots of mean lengths of all 1980 saugers. A - using all points, B - deleting first point.

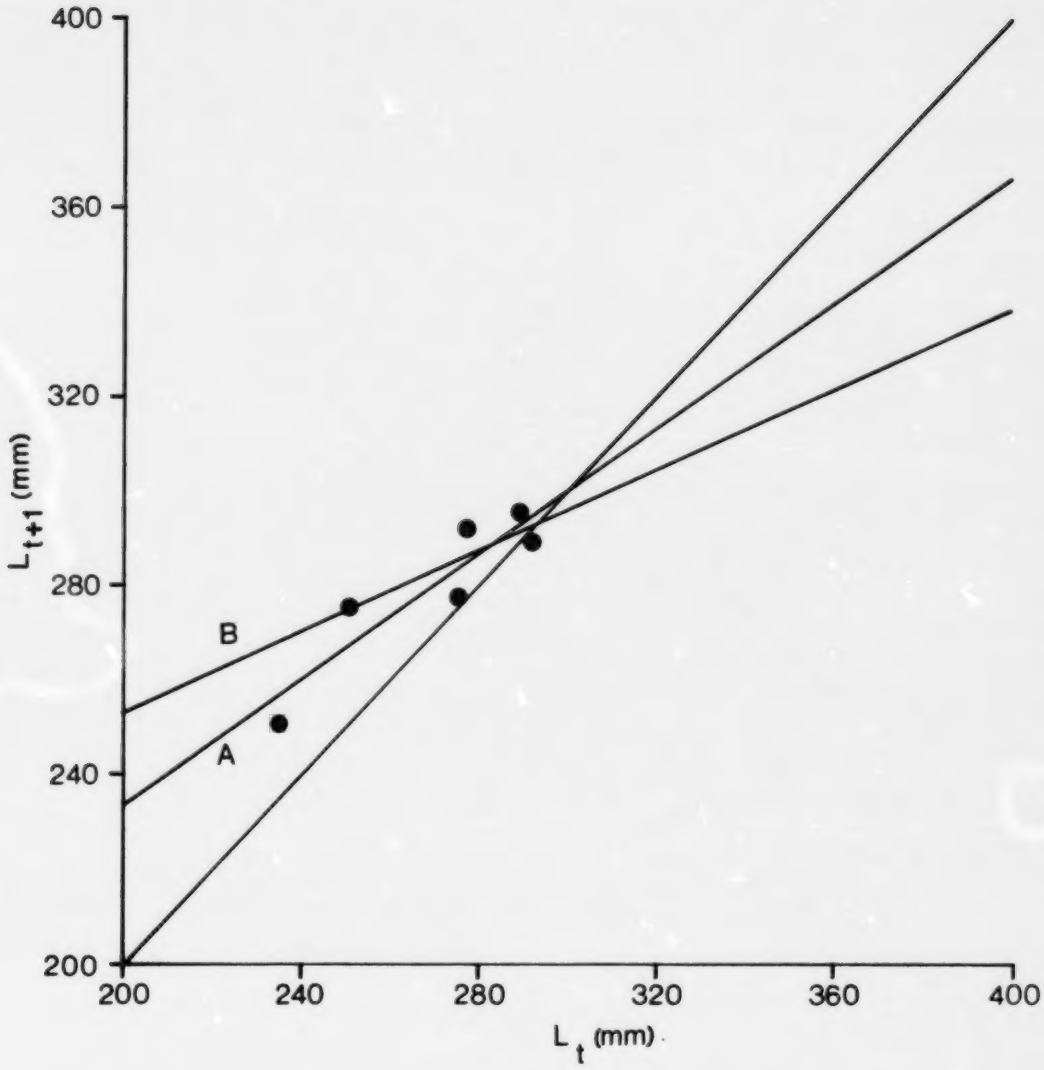


Fig. 11. 1979 male sauger Walford plots. A - including all points, B - deleting first point.

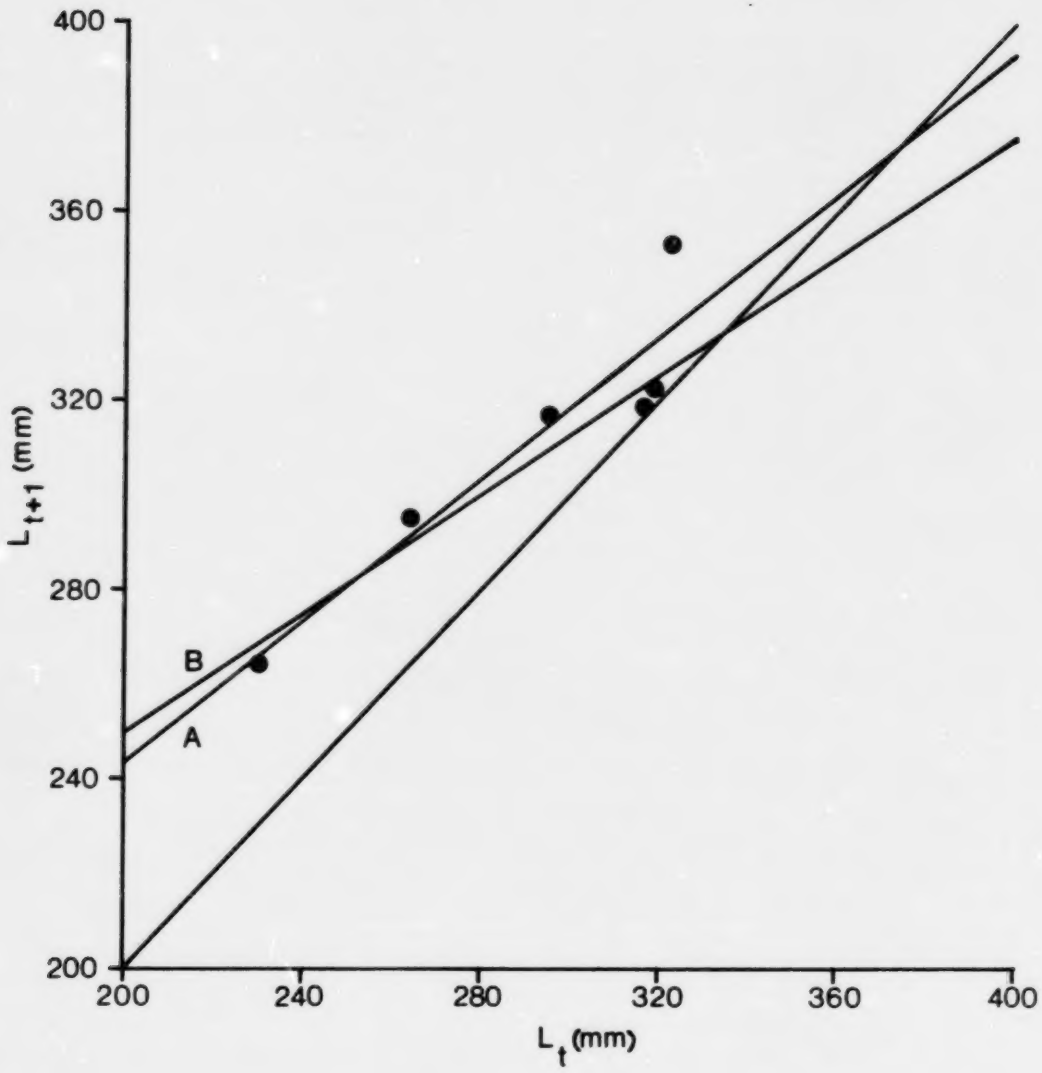


Fig. 12. 1979 female sauger Walford plots. A - including all points. B - deleting last point.

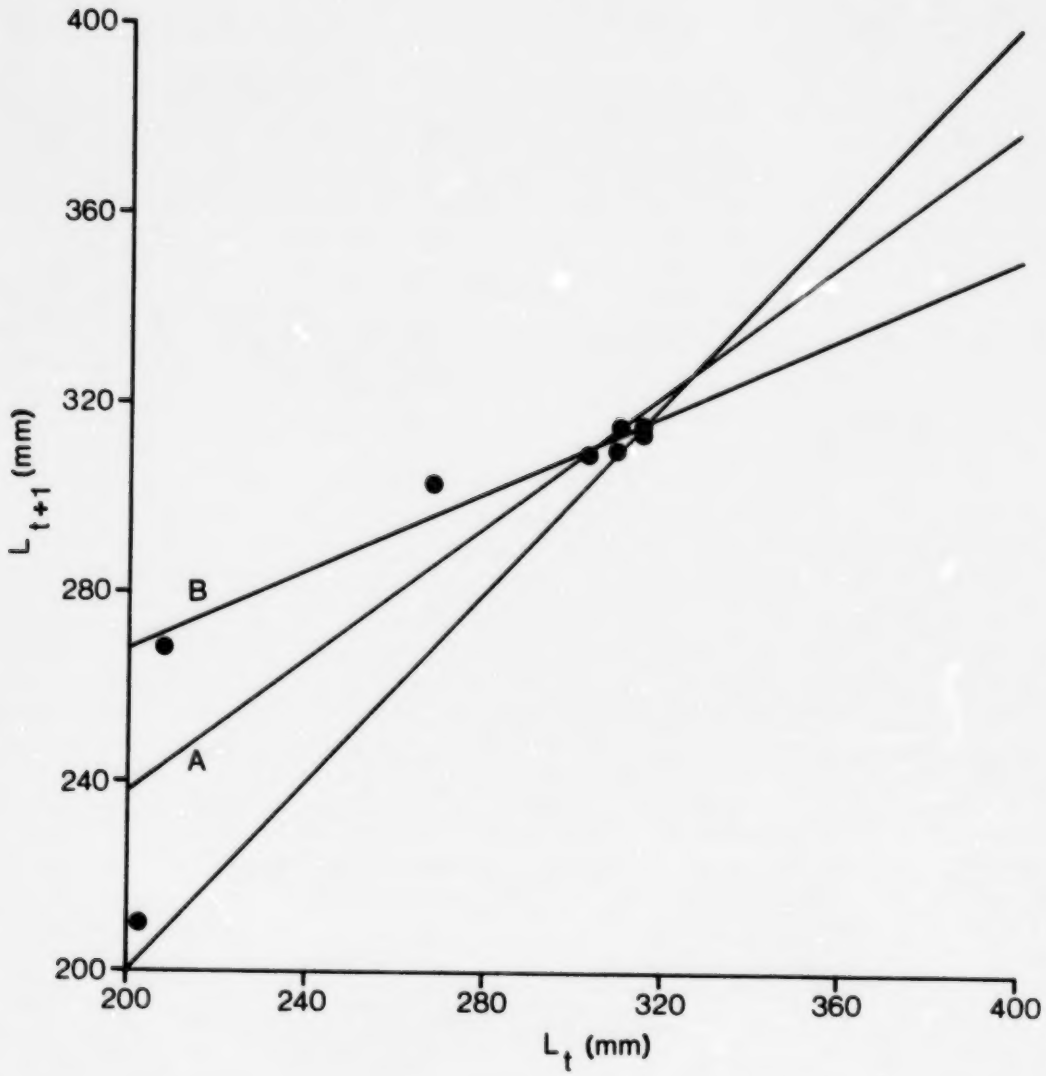


Fig. 13. 1980 male sauger Walford plots. A - including all points.
B - deleting first point.

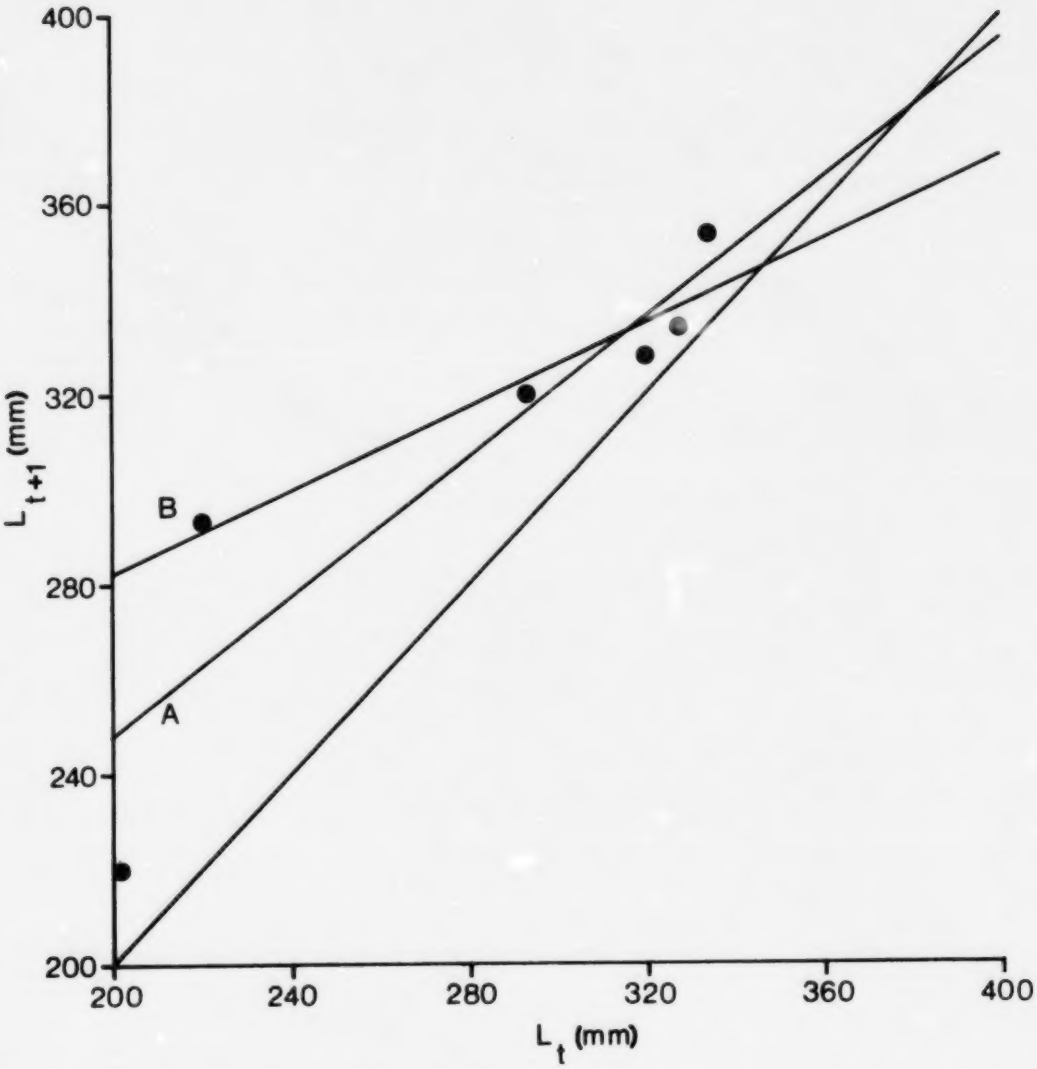


Fig.14. 1980 female sauger Walford plots. A - including all points. B - deleting first point.

Transforming age-specific mean lengths according to the exponential and von Bertalanffy growth models resulted in substantial increases in correlation coefficients (Table 6). Elimination of mean lengths of saugers older than 4 years resulted in a higher R of the exponential growth curve even though both growth rates were significant in 1979 and in 1980 (Table 7, Fig. 15). An analysis of covariance revealed no significant differences ($P = 0.05$) between slopes or elevations of the 1979 and 1980 combined sexes exponential growth curves (Table 8). The exponential growth rates of females were higher than those of males in both years (Table 7). Sex-specific differences in exponential growth rates were significant ($P = 0.05$) in 1979 but not in 1980 (Table 8).

Elimination of mean lengths of 7 and 8 year old saugers resulted in a higher R and lower t_o of the 1979 von Bertalanffy growth equation (Table 9, Fig. 16). The 1979 Brody growth coefficient, 0.568, was slightly lower than its 1980 counterpart, 0.588. Mean lengths of 7 - 9 year old saugers were deleted from both 1980 von Bertalanffy growth curves (Fig. 17). The use of $L_\infty = 332$ mm and inclusion of the mean length of young-of-the-year saugers resulted in a slightly higher R and smaller t_o in the first 1980 von Bertalanffy curve (Table 9). In 1979, males grew slower than females and attained a lower asymptotic size (Table 9, Figs. 18 and 19). In 1980, the

Table 6. Correlation coefficients of various growth curves of southern basin saugers, 1979 and 1980.

Curve type	Transformation					
	Untransformed		Exponential		von Bertalanffy	
	1979	1980	1979	1980	1979	1980
Combined sexes	0.853	0.839	0.946	0.962	0.962-0.993	0.945-0.956
males	0.934	0.856	0.975	0.934	0.769-0.967	0.961
females	0.955	0.937	0.982	0.971	0.979	0.969-0.981

Table 7. Exponential growth curves for various sauger length data, 1979 and 1980.

Curve type	Equation		Test F value and d.f.
1979 combined sexes, ages 0 - 8	Log_e length = 4.984 + 0.422 $\log_e$ age	0.946	59.59 (1,7)
1979 combined sexes, ages 0 - 4	Log_e length = 4.966 + 0.555 $\log_e$ age	0.973	52.73 (1,3)
1979 males, ages 2 - 8	Log_e length = 5.352 + 0.170 $\log_e$ age	0.975	96.10 (1,5)
1979 females, ages 2 - 8	Log_e length = 5.262 + 0.286 $\log_e$ age	0.982	131.41 (1,5)
1980 combined sexes, ages 0 - 9	Log_e length = 5.135 + 0.349 $\log_e$ age	0.962	100.09 (1,8)
1980 combined sexes, ages 0 - 4	Log_e length = 5.113 + 0.456 $\log_e$ age	0.995	303.60 (1,3)
1980 males, ages 1 - 9	Log_e length = 5.293 + 0.235 $\log_e$ age	0.934	47.69 (1,7)
1980 females, ages 1 - 7	Log_e length = 5.263 + 0.323 $\log_e$ age	0.971	83.12 (1,5)

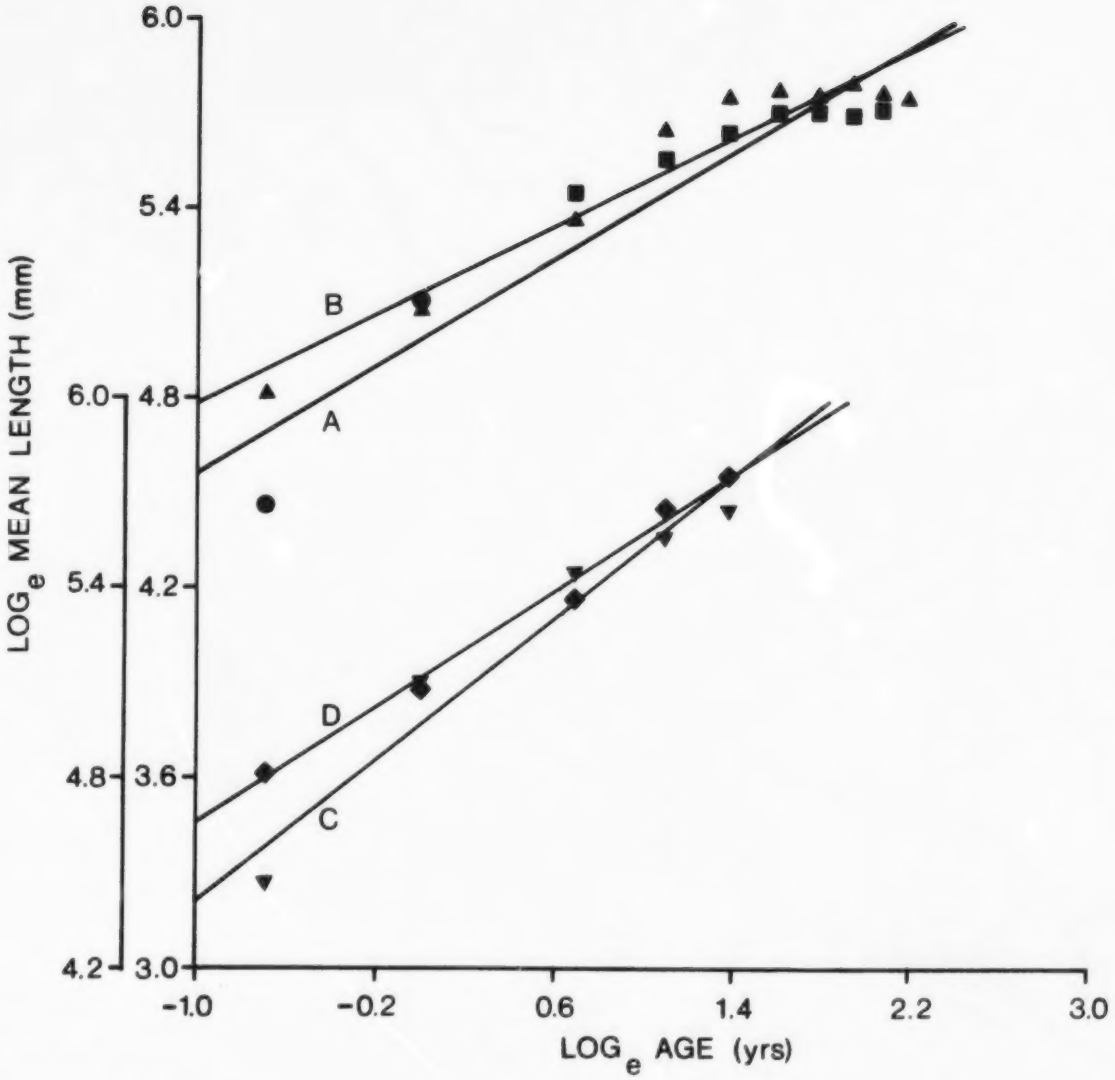


Fig. 15. Exponential growth curves of saugers. A - 1979 curve including ages 0 - 9. B - 1980 curve including ages 0 - 10. C - 1979 curve including ages 0 - 4. D - 1980 curve including ages 0 - 4.

Table 8. Covariance analyses of sauger growth curves.

Comparison	Slopes F value and d.f.	Elevation F value and d.f.
1979 exponential growth versus 1980 exponential growth, combined sexes, all mean lengths	1.319 (1,15)	1.393 (1,16)
1979 exponential growth versus 1980 exponential growth, combined sexes, mean lengths of ages 0-4	1.499 (1, 6)	2.406 (1, 7)
1979 male versus female exponential growth, all mean lengths	10.475 (1, 9)	13.867 (1,10)
1980 male versus female exponential growth, all mean lengths	0.931 (1,10)	3.016 (1,11)

Table 9. Von Bertalanffy growth curves and related equations for various sauger length data, 1979 and 1980.

Type	Equation	R	Test F value and d.f.
1979 combined sexes, ages 0 - 8, L_∞ = 312mm	$\text{Log}_e (L_\infty - l_t) = 5.316 - 0.439t$ $l_t = 312 (1-e^{-0.439 (t - 0.973)})$	-0.962	86.95 (1,7)
1979 combined sexes, ages 0 - 6 L_∞ = 312mm	$\text{Log}_e (L_\infty - l_t) = 5.606 - 0.568t$ $l_t = 312 (1-e^{-0.568 (t - 0.241)})$	-0.993	358.34 (1,5)
1979 males, ages 2 - 8, L_∞ = 300 mm	$\text{Log}_e (L_\infty - l_t) = 5.082 - 0.436t$ $l_t = 300 (1-e^{-0.436 (t - 1.426)})$	-0.967	71.70 (1,5)
1979 males, ages 3 - 7, L_∞ = 292.5mm	$\text{Log}_e (L_\infty - l_t) = 6.309 - 0.878t$ $l_t = 292.5 (1-e^{-0.878 (t + 0.718)})$	-0.769	4.33 (1,3)
1979 females, ages 2 - 7, L_∞ = 335mm	$\text{Log}_e (L_\infty - l_t) = 5.502 - 0.451t$ $l_t = 335 (1-e^{-0.451 (t - 0.692)})$	-0.979	90.32 (1,4)
1980 combined sexes, ages 0 - 6, L_∞ = 332mm	$\text{Log}_e (L_\infty - l_t) = 5.554 - 0.588t$ $l_t = 332 (1-e^{-0.588 (t - 0.426)})$	-0.956	52.91 (1,5)

1980 combined sexes, ages 1 - 6, L_∞ = 340mm	$\text{Log}_e (L_\infty - l_t) = 5.593 - 0.503t$ $l_t = 340 (1\text{-}e^{-0.503 (t - 0.468)})$	-0.945	33.32 (1,4)
1980 males, ages 2 - 8, L_∞ = 315.8mm	$\text{Log}_e (L_\infty - l_t) = 6.792 - 1.011t$ $l_t = 315.8 (1\text{-}e^{-1.011 (t + 1.026)})$	-0.961	59.86 (1,5)
1980 females, ages 2 - 7, L_∞ = 381mm	$\text{Log}_e (L_\infty - l_t) = 5.534 - 0.312t$ $l_t = 381 (1 - e^{-0.312 (t - 0.709)})$	-0.969	60.89 (1,4)
1980 females, ages 2 - 6, L_∞ = 346.8mm	$\text{Log}_e (L_\infty - l_t) = 5.778 - 0.565t$ $l_t = 346.8 (1 - e^{-0.565 (t - 0.125)})$	-0.981	77.35 (1,3)

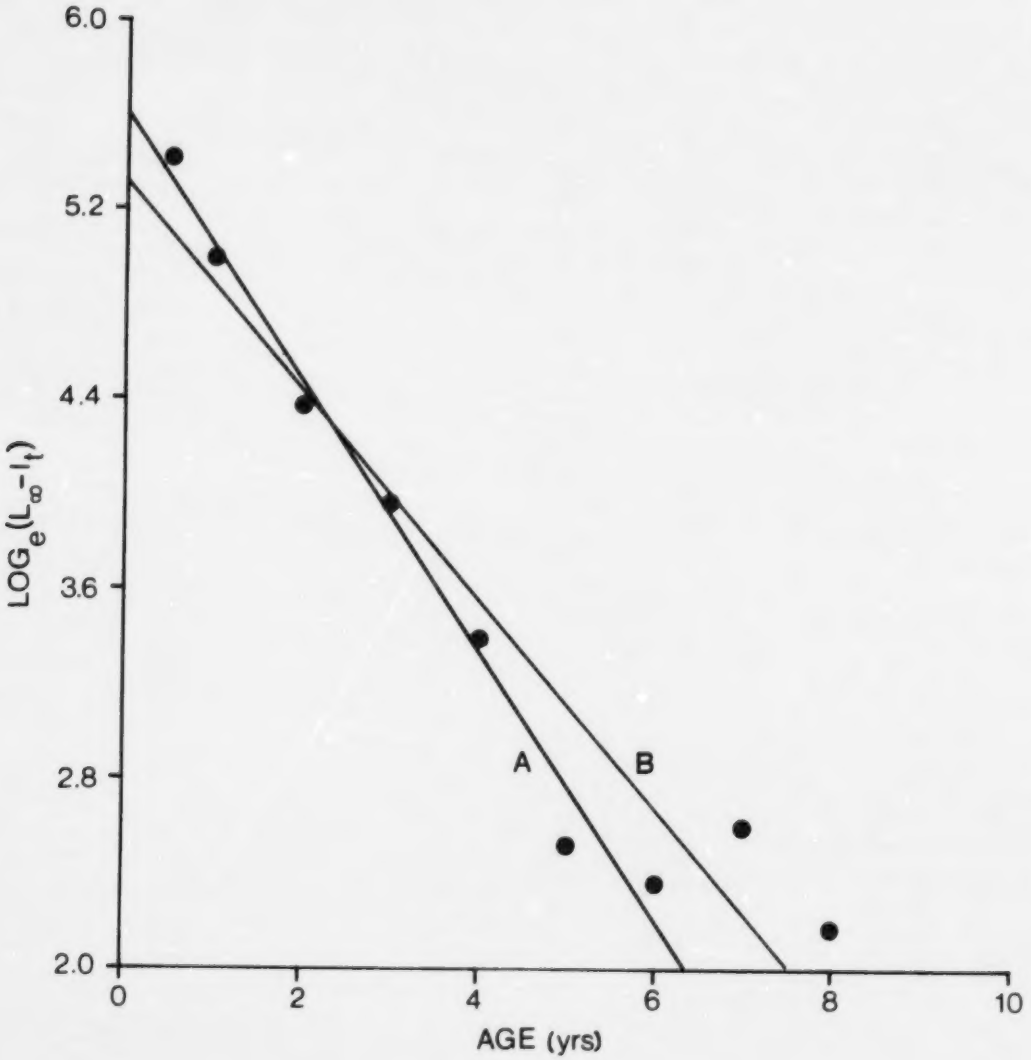


Fig. 16. Plots of $\log_e (L_\infty - l_t)$ versus t for 1979 saugers. A - deleting mean lengths at ages 7 and 8. B - using all points.

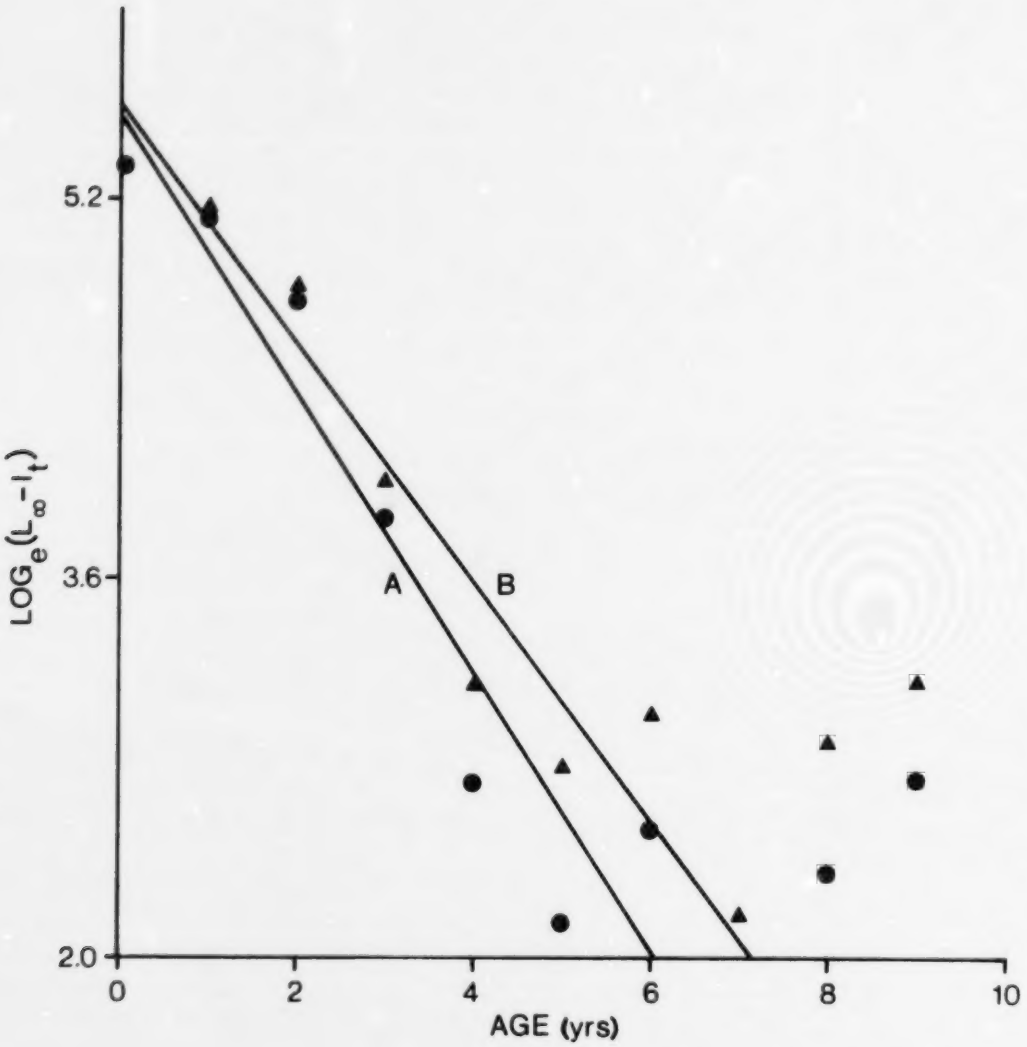


Fig. 17. Plots of $\log_e (L_\infty - l_t)$ versus t for 1980 saugers. A - using L_∞ = 332 mm and ages 0 - 6. B - using L_∞ = 340 mm and ages 1 - 6.

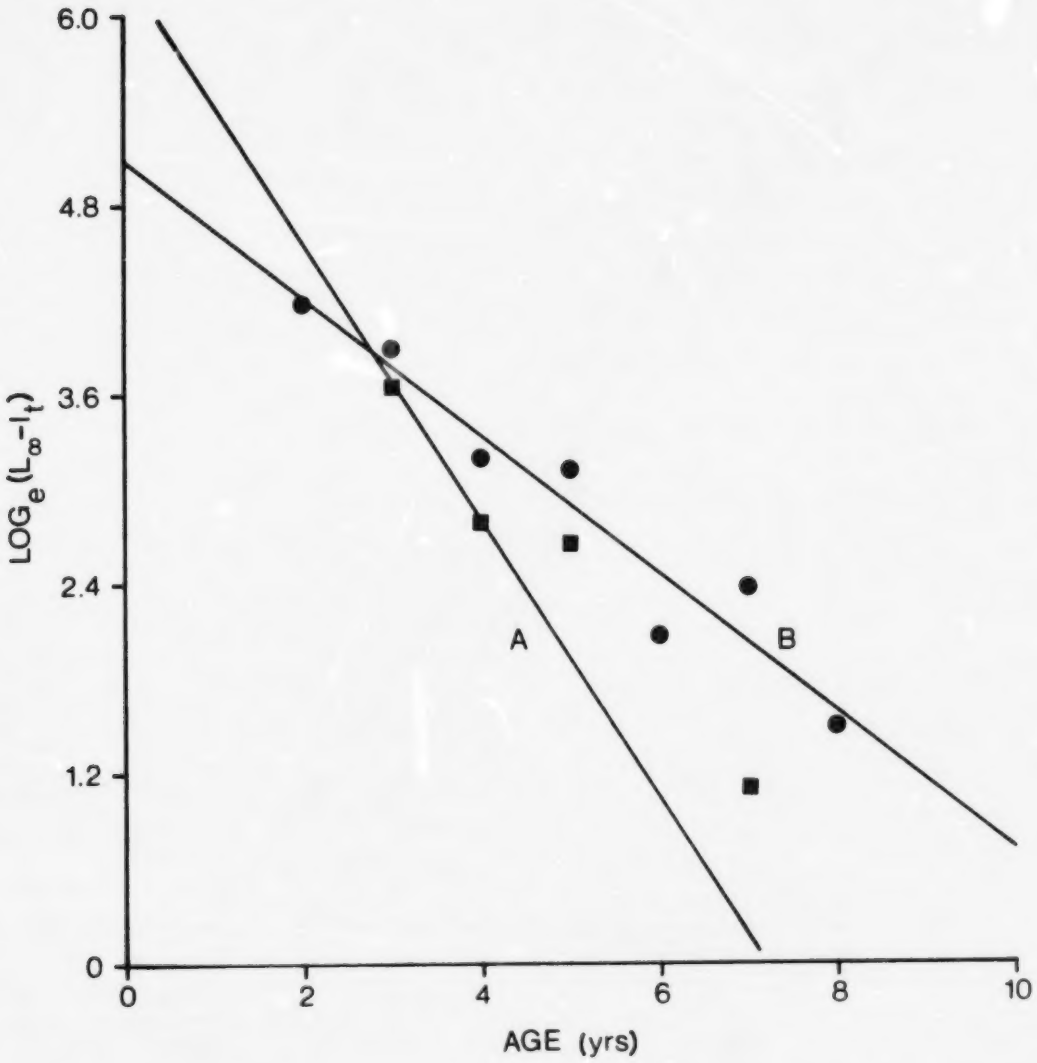


Fig. 18. Plots of $\log_e$ (L_∞ - l_t) versus t for 1979 male saugers.
A - using L_∞ = 292.5 mm. B - using L_∞ = 300 mm.

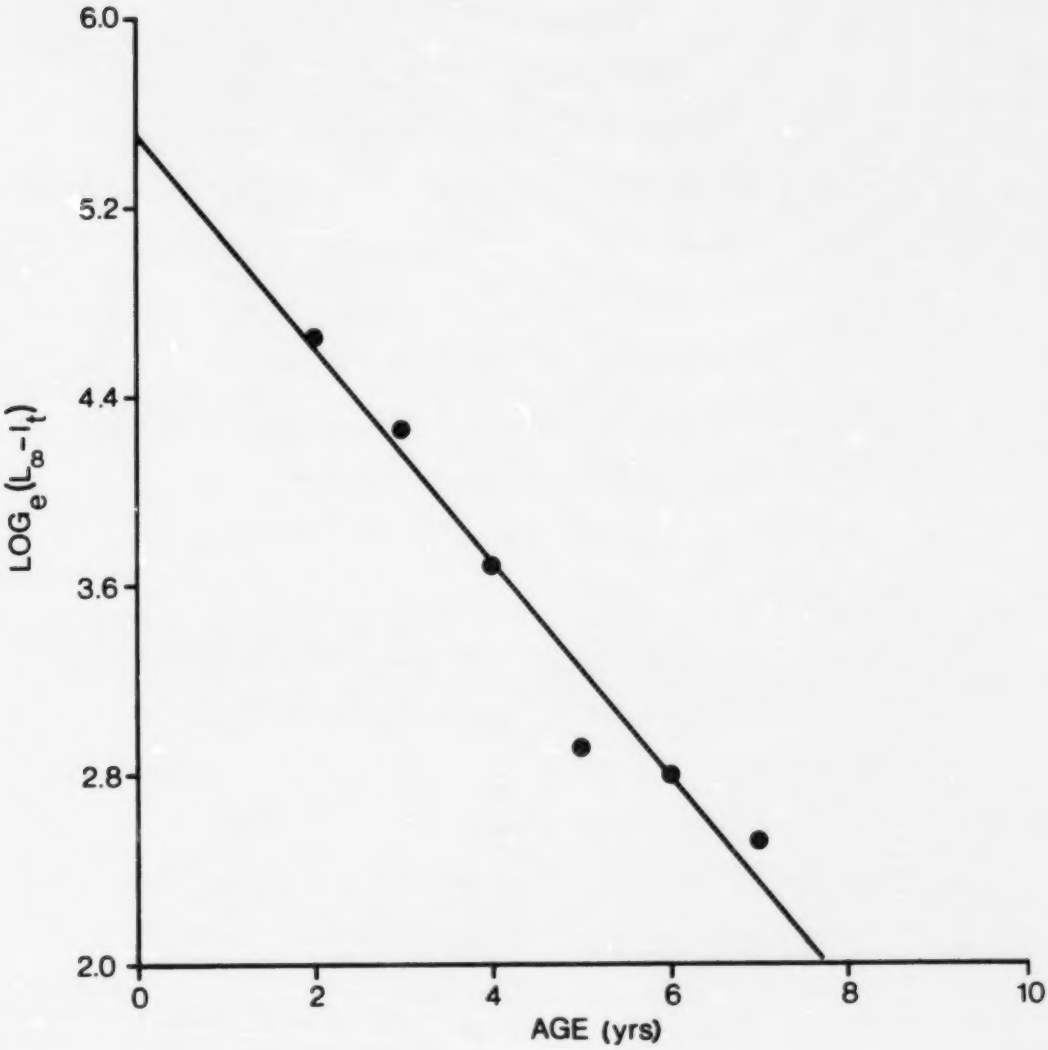


Fig. 19. Plot of $\log_e$ (L_∞ - l_t) versus t for 1979 female saugers using L_∞ = 335 mm.

asymptotic size of females was still greater than that of males but males had a faster growth rate (Table 9, Figs. 20 and 21).

The slopes of seasonal growth curves fitted by regression to untransformed mean lengths of y-o-y and yearling saugers (Table 10) were not significantly different between 1979 and 1980 (y-o-y ANCOVA test F = 2.80, 1 and 6 d.f., P = 0.05, yearling ANCOVA test F = 0.185, 1 and 12 d.f., P = 0.05). However, the 1980 y-o-y and yearling linear growth curves were significantly higher than their 1979 counterparts (y-o-y ANCOVA test F = 11.12, 1 and 7 d.f., P = 0.05, yearling ANCOVA test F = 4.73, 1 and 13 d.f., P = 0.05).

No significant differences occurred between linear warming rates of water (Table 11) during 1979 and 1980 (ANCOVA test F = 4.81, 1 and 6 d.f., P = 0.05) but the 1980 water temperatures were significantly higher than they were in 1979 during the first 63 days of sampling (ANCOVA test F = 11.97, 1 and 7 d.f., P = 0.05).

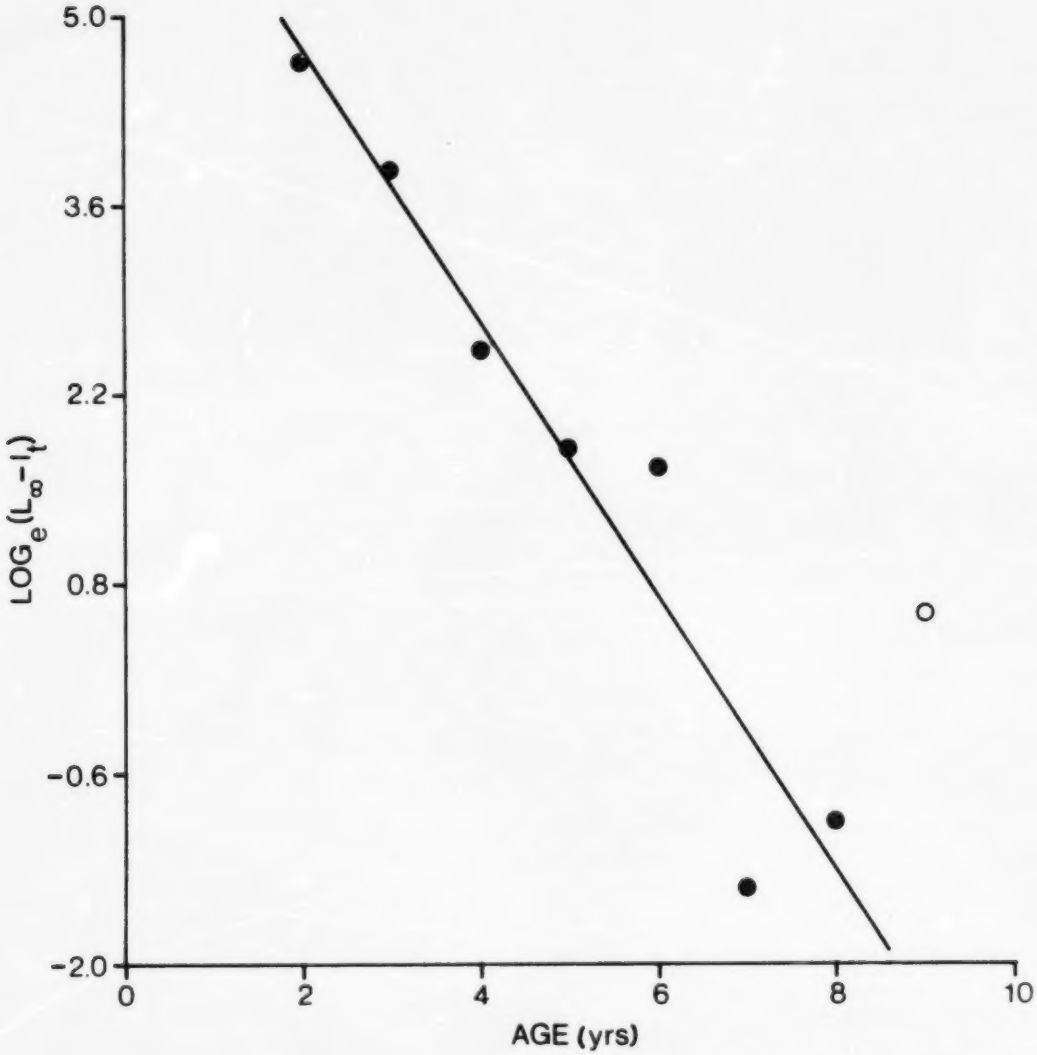


Fig. 20. Plot of $\log_e (L_\infty - l_t)$ versus t for 1980 male saugers. L_∞ = 315.8 mm and the open circle was deleted from analysis.

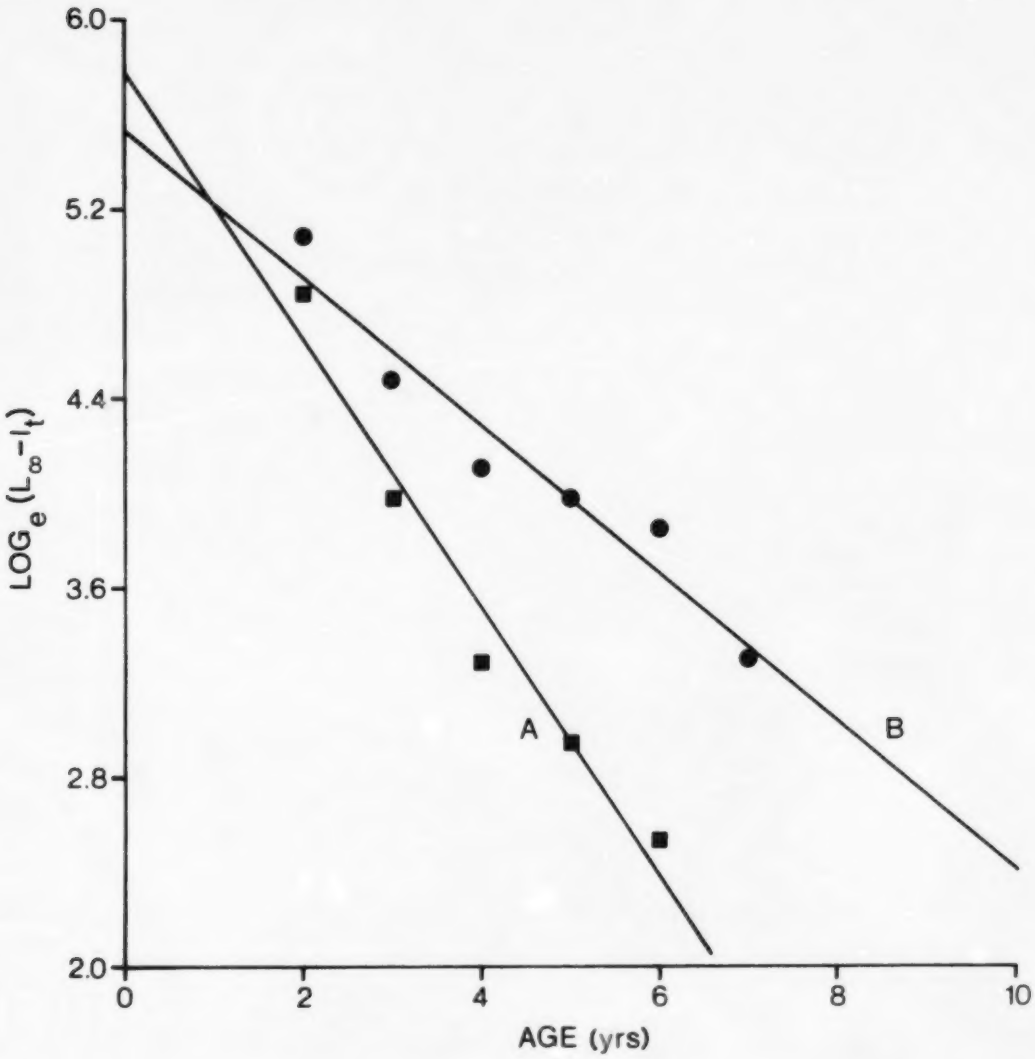


Fig. 21. Plots of $\log_e$ (L_∞ - l_t) versus t for 1980 female saugers. A - using L_∞ = 346.8 mm and ages 2 - 6. B - using L_∞ = 381 mm and ages 2 - 7.

Table 10. Seasonal changes in mean lengths of young-of-the-year and yearling saugers caught at Patricia Beach during 1979 and 1980.

Date	Time (days)	Year			
		1979		1980	
		Mean length (mm)	Sample size	Mean length (mm)	Sample size
Yearlings					
May 28	0	86.8	20	84.4	76
June 17	20	88.9	33	97.4	67
July 3	36	96.0	55	99.1	57
July 16	49	111.0	35	118.1	24
July 30	63	117.0	17	137.5	69
Aug. 15	79	138.0	9	140.0	6
Aug. 30	94	150.0	1	156.1	20
Sept. 12	107	161.0	11	165.2	35
Sept. 25	120	162.5	72	167.5	76*
Oct. 6	131	165.5	43	162.5	57*
Oct. 16	141	165.0	14	165.7	81*
Y-O-Y					
July 16	0	43.5	100	54.1	7
July 30	14	62.0	88	64.5	10
Aug. 15	30	70.5	100	80.3	3
Aug. 30	45	76.3	80	87.0	4
Sept. 12	57	87.6	21	113.0	1
Sept. 25	70	85.1	76	125.4	15
Oct. 6	81	86.1	10	123.0	10*
Oct. 16	91	86.0	4	122.0	34*

*Culled fish from 3 inch commercial gillnets.

Table 11. Water temperatures at Patricia Beach during 1979 and 1980.

Date	Time (days)	Temperature (°C)	
		1979	1980
May 28	0	6	15
June 17	20	15	17
July 3	36	18	21
July 16	49	19	22
July 30	63	21	23
August 15	79	19	21
August 30	94	18	19
September 12	107	15	16
September 25	120	12	13
October 6	131	7	9
October 16	141	5	6

DISCUSSION

Saugers grew larger in 1980 compared to 1979 with the exception of the 2+ fish. The 1979 spring season was short with break up not occurring until late May. The 1980 spring season was relatively longer with break up occurring in mid-April. Water temperatures were significantly higher in 1980 resulting in a longer optimum growing season.

The majority of juvenile sauger growth took place in water temperatures of 15°C - 22°C. This range of temperature lasted approximately 87 days in 1979 and 107 days in 1980 (Tables10 & 11). Therefore the 1980 growing season was approximately 20 days longer than the 1979 season. Koenst and Smith (1975) stated that sauger fry development takes place in water temperatures of 15°C - 21°C and found that under laboratory conditions, 22°C was the optimum temperature for juvenile sauger growth. Water temperatures of 21°C - 22°C were recorded for 4 of the bi-weekly sampling periods in 1980 compared to one period in 1979 (Table 11).

Growing seasons in southern sauger populations are longer due to warmer climatic conditions resulting in longer periods of optimum water temperatures for sauger growth (Hassler 1955, Hokanson 1976). A longer growing season is one of the main environmental factors resulting in southern sauger populations reaching a larger size in a shorter time span compared to saugers examined from southern Lake Winnipeg. Hassler (1955) reported a surface water temperature of 15°C or higher for 214 days for a sauger growth study carried out in Norris Reservoir,

Tennessee. These results were in sharp contrast to the two years of water temperature data collected in southern Lake Winnipeg which showed an average time span of 97 days in which water temperatures were 15°C or higher.

Nepsy and Colby (in prep.) calculated a significant relationship between accumulated growing degree days above 5°C and length at first annulus for walleye populations ranging from northern Ontario to Texas. Growing degree days was considered to represent energy availability. Temperature requirements and effects on percid populations were well documented by Hokanson (1976).

Stock exploitation, interspecific competition, and lake productivity also interact to affect growth rates of fish populations. For whitefish, Healey (1975) stated that when an unexploited population is initially fished, compensatory growth does not occur until the larger, older fish have been removed. As exploitation continues, growth rates increase. Fish from lightly exploited stocks are characterized by relatively slow growth rates and a wide variation in growth. Fish from heavily exploited stocks grow rapidly and show less variation in growth (Healey 1975, Parsons 1967). Weatherly (1976) suggested that there is a biological limit of growth rate. Thus the difference between growth rate of a fish stock before exploitation and the maximum growth rate may be used as an indicator of the population's resiliency to exploitation. Examples of the effects of exploitation on growth and maturity are described by Miller (1947, 1956) for Pigeon Lake whitefish, for Great Slave Lake stocks (Kennedy 1953, Bond and Turnbull 1973), salmonid communities in oligotrophic lakes (Regier and Loftus 1972), and Lake Erie walleyes (Wolfert 1969).

Fish growth is responsive to energy and nutrient availability and population density. Swenson and Smith (1973) showed that digestion rates are similar among different populations of walleyes. Digestion rate increases exponentially with temperature (Hoffman 1969).

The relationship of growth and population density is still somewhat obscure. Dobie (1956, 1969) showed that growth of y-o-y walleyes raised in ponds is inversely related to density. Keller (1964) stated that the increase in growth of yearling walleyes from Lake Erie from 1920 to 1962 was due to a decrease in density. However, Smith and Pycha (1960) claimed that changes in spawning population size did not affect growth of yearlings in Red Lake, Minnesota.

South basin saugers reach a minimum commercial marketable size of 254 mm at a mean age of 3+ (Table 3). Current research has shown that the mean length at maturity for female sauger was 303.61 mm in the south basin (Olynyk 1980). The minimum marketable size should be one that ensures that saugers spawn at least once before being recruited into the fishery. According to female sauger growth data (Table 4), a minimum marketable size of at least 303.61 mm should be set. This minimum marketable size would allow south basin sauger to spawn once before being recuited into the fishery resulting in a more stable and profitable sauger fishery in the basin.

The best growth curves of male, female and combined sexes saugers from Lake Winnipeg presented in this study are those that are characterized by a high correlation coefficient, a low estimate of t_o and an asymptotic size that closely approximates the maximum observed size in various samples. The best combined sexes von Bertalanffy growth curves for 1979 and 1980 presented in this study are $l_t = 312\ (1 - e^{-0.568(t - 0.241)})$ and $l_t = 332\ (1 - e^{-0.588(t - 0.426)})$ respectively. These curves are characterized by a relatively low Brody growth coefficient as compared to the southern Lake Winnipeg sauger growth curve based on scale ages (Lysack, 1980). Since scales underestimate the age of older saugers from Lake Winnipeg (Lysack, 1980), it follows that a growth curve based on otoliths would yield a lower growth rate than one based on scale ages. Notice that the age-specific mean lengths (based on scale ages) of southern Lake Winnipeg saugers are among the highest of those listed in Table 12 (Lysack 1980). Since the southern Lake Winnipeg sauger population is overexploited, growth is extremely rapid because the stock is attempting to compensate for the rapid removal of fish recruited to commercial nets.

Since the use of scale ages tends to overestimate sauger growth rates and make the growth curve more linear than it really is, it is strongly recommended that growth and maturity studies be based on otolith ages. Use of otoliths will provide empirical estimates of all growth parameters.

Growth comparisons of southern Lake Winnipeg saugers with sauger growth in other lakes in Canada and the United States are listed in Table 12. The southern sauger populations grow larger

over a time span of one year than the southern Lake Winnipeg saugers. Growth comparisons of saugers from Lake of the Woods (Carlander 1950) and Lake Nipigon (Hart 1928) were similar to those recorded for southern Lake Winnipeg in this present study.

Table 12. Calculated growth (fork length) of saugers reported from various lakes.

Locality	Number of fish	Average calculated fork length for each year of growth								
		1	2	3	4	5	6	7	8	9
Lake Winnipeg (Present study otolith ages)	-Combined (1415)	105.1	164.6	223.4	269.3	298.5	307.9	313.8	320.3	334.3
	-Males (414)	-	-	221.5	259.7	289.4	293.5	301.2	302.4	305.5
	-Females (439)	-	-	225.2	278.8	307.7	322.2	326.4	338.2	363.0
Lake Winnipeg (Lysack (1980) scale ages)	-Combined (666)	-	195.0	283.2	292.6	300.5	307.6	-	-	-
Lake Manitoba Kennedy (1949)	-Combined (1039)	-	-	241.3	292.1	322.6	342.9	360.7	381.0	398.8
Lake of the Woods Minnesota (Carlander 1950)	-Combined (883)	86.0	159.4	185.9	251.1	301.9	330.8	342.9	365.0	374.3
Lake Nipigon Ontario (Hart 1928)	-Combined (64)	-	-	226.9	251.1	297.3	301.9	316.3	350.2	371.8
Lake Erie, Ohio (Deason 1933)	(905)	94.2	190.8	251.1	294.6	328.4	381.5			
Garrison Reservoir, North Dakota (Carufel 1963)	-Males (99)	115.9	205.3	277.7	340.5	425	-			
	-Females (222)	120.8	212.5	301.9	379.2	444.3	557.9			

Lewis & Clark Lake, South Dakota Vanicek (1964)	-Combined	(479)	152.1	297.0	393.6	458.9	495.1	511.9		
Lake Winnebago, Wisconsin (Priegel 1969)	-Males	(784)	118.3	229.4	292.2	318.7	338.1	357.4	369.5	381.6
	-Females	(957)	127.9	239.1	294.6	321.9	340.5	359.9	371.8	381.6
Norris Reservoir, Tennessee (Hassler 1957)	-Combined	(3393)	202.8	321.2	276.7	415.4	449.2	473.4	490.2	

RECOMMENDATIONS

1. The present minimal commercial marketable size of saugers (254 mm) in the south basin should be increased to protect pre spawners. This study shows that a minimal marketable size of 303.6 mm is needed to allow saugers to spawn once before being recruited into the fishery.
2. It is strongly recommended that otolith ages be used for future growth and maturity studies on saugers in Lake Winnipeg.

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